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AN ADHESIVE SHEET FOR SURFACE OF BUILDINGS AND A SURFACE TREATMENT METHOD FOR BUILDINGS

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AN ADHESIVE SHEET FOR SURFACE OF BUILDINGS AND A SURFACE TREATMENT METHOD FOR BUILDINGS

[Ken'zobutsuhyomen'haritsukeyo shiito
oyobi ken'zobutsuhyomen shorihoho]

Applicants: 592189376
Osada Giken KK
6F 2 Kanaoka Building
9-2-30 Tani-cho
Chuo-ku, Osaka-fu

000228707
Nippon Conveyor Co. Ltd.
2-1-1 Midorigaoka
Higashi-shi, Osakafu

Inventors: Hideharu Nagata
c/o Osada Giken KK
6F 2 Kanaoka Building
9-2-30 Tani-cho
Chuo-ku, Osaka-fu

Minoru Kondoh
c/o Nippon Conveyor Co. Ltd.
2-1-1 Midorigaoka
Higashi-shi, Osakafu

Agent: Hisayoshi Nagata
Patent attorney

[*There are no amendments to this patent.*]

(54) [Title of the invention]

An adhesive sheet for the surface of buildings and a surface treatment method for buildings

(57) [Abstract] (Rewritten)

[Objective] The objective of the present invention is to provide a rapid and simple method of installation to produce an aesthetic surface for buildings which has not been achieved in the past.

[Constitution] Optical fibers are installed between the flat surface of a building and an adhesive sheet in such a manner that the optical fibers are secured by the adhesive sheet and one end of the optical fibers sticks out from the adhesive sheet.

[*Translator's note: Legend copied from p. 4 of source document*]

1: Adhesive sheet of the present invention

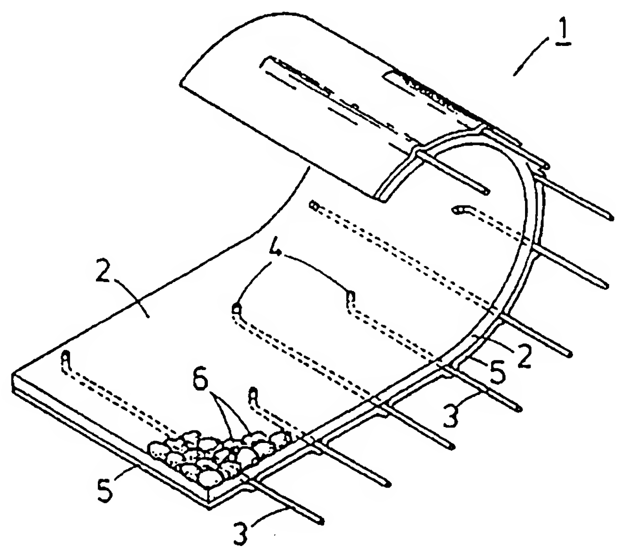
2: Butyl rubber sheet

3: Optical fiber cable

4: One end of cable

5: Release sheet

6: Granular material



[Claims of the invention]

[Claim 1] An adhesive sheet for the surface of buildings used on the surface of buildings wherein an adhesive sheet is used as the base material, and optical fibers are installed in such a manner that the optical fibers penetrate the base material and one end [of the fiber] is exposed at the surface.

[Claim 2] Optical fibers are installed between the flat base of a building and an adhesive sheet in such a manner that the optical fibers are secured by the adhesive on the sheet and one end of the optical fibers protrudes from the adhesive sheet.

[Detailed explanation of the invention]

[0001]

[Field of industrial application] The present invention pertains to an adhesive sheet for the surface of buildings and a surface treatment method for buildings.

[0002]

[Prior art] Buildings in this case include normal buildings, as well as bridges, bridge supports, roads with a relatively smooth surface, for example, tracks used for track and field events, jogging paths, footpaths in parks, courtyards in buildings, etc.

[0003] In the following, the present invention is explained with sidewalks used as an example. Sidewalks, in particular, sidewalks in parks and theme parks require a good surface appearance. Unlike utility roads, many different pavements have been used in the past. For example, tiling in a mosaic form, stone pitching with natural stones, installation of synthetic resin plates, etc. can be mentioned. However, the above-mentioned methods are accompanied by many problems such as complex procedures, unknown construction period, requirement of skilled workers, and high cost.

[0004] For this reason, in recent years, rubber or plastic sheets with aesthetic surfaces have been used for sidewalks because of the ease of installation.

[0005]

[Problems to be solved by the invention] However, the aesthetic surface cannot be seen at night, or is difficult to see no matter what type of installation method is used. In recent years, aesthetic surfaces that are easy to see even in the dark are in demand. It is possible to use a luminous paint or to bury electric lights, but control of the lighting is not possible when a luminous paint is used, and when partial peeling of the paint occurs, it is unattractive. When electric lights are buried, replacement of the bulbs is impossible, or very expensive equipment and installation is required.

[0006] Thus, a sidewalk with an aesthetic appearance that is clearly visible at night has been in demand for a long time for use in the above-mentioned areas.

[0007]

[Means to solve the problems] Based on the above information and as a result of their continuous effort, the inventors produced an adhesive sheet for the surface of buildings and the surface treatment for buildings of the present invention. Thus, the present invention is an adhesive sheet for the surface of buildings used for treating the surface of buildings wherein an adhesive sheet is used as the base material, and optical fibers are installed in such a manner that the optical fibers penetrate the base material and one end of the fiber is exposed at the surface, and an installation method wherein optical fibers are installed between the flat surface of a building and the adhesive sheet in such a manner that the optical fibers are secured by the adhesive of the sheet and one end of the optical fiber protrudes from the adhesive sheet.

[0008] In this case, an adhesive sheet means a sheet made of a rubber-like material having semi-permanent adhesion or a plastic sheet coated with an adhesive. For rubber-like materials having semi-permanent adhesion, non-vulcanized butyl rubber sheets that are commercially available can be mentioned as typical examples. Needless to say, the material is not limited to the above-mentioned example, and any rubber with similar properties can be used. The thickness of the rubber sheet is not especially limited, and in general, a thickness in the range of 0.5 to 5.0 mm is appropriate.

[0009] In this case, a plastic sheet coated with an adhesive can be used as well. When a pressure-sensitive adhesive is coated, an adhesion equal to that of the above-mentioned butyl rubber sheet can be achieved. The degree of adhesion can be appropriately selected depending on the type of buildings used, for example, roads or buildings, position of installation, for example, horizontal or vertical, back surface such as the case of ceiling, etc. The above-mentioned commercial butyl rubber sheets have adequate adhesion and have been effectively used in vertical applications.

[0010] In the optical fiber, the light travels inside the optical fiber while total internal reflection occurs, and the light is emitted from the end of the fiber. Needless to say, optical fibers of many different sizes are commercially available. In this case, the light enters from one end and is released from the other end with little attenuation; thus, they are widely used for communication and many different types of decorations.

[0011] As for installation (securing) of the above-mentioned fiber to the adhesive sheet, it is simply secured to the back surface with the adhesive of the sheet. Needless to say, handling is difficult when used as is; thus, a release sheet is applied over [the

adhesive]. Also, one end of the above-mentioned fiber is exposed to the surface, and the other end extends out from the sheet along one edge. The level of exposure of [each optical fiber cable] is not especially limited, and the optical fibers can be trimmed to make them uniform at the construction site. As for the other end that protrudes from the edge of the sheet, when a connector cable is used, a short length is left protruding, but when a connector cable is not used, it requires a length long enough to reach the light source.

[0012] Furthermore, many different types of aesthetic treatments can be applied to the surface of the above-mentioned sheet. For example, pulverized (granulated) natural stones and ceramic can be bonded to the surface to produce an aggregate finish, or other hard cosmetic sheets can be bonded. However, it is necessary to produce through-pores in the bonding object when a material is used for which easy installation of the cable is not possible.

[0013] Granular materials are materials molded or pulverized in the shape and size of pebbles (having diameters of approximately 2~10 mm), and needless to say, a flat or elongated material can be used as well. Furthermore, rubbers and plastics may be used. Especially when high elasticity is required, rubber chips can be used effectively.

[0014] For the above-mentioned granular materials, those containing a variety of sizes or different colors can be mixed, as desired. Also, a designs can be made using granular materials with specific colors for specific areas using the patterns such as described below. In this case, an aesthetic effect can be provided during daylight hours when the light from the optical fibers is not visible.

[0015] It is desirable to apply the above-mentioned granular material without voids. In other words, no area of the sheet is left exposed, but theoretically, it is not possible to apply without voids; thus, it means nearly the entire area is covered. "Nearly the entire area" means that no exposed areas exist that are large enough for granules of the material to fit into. As for the application method of the above-mentioned granular material, a method wherein the amount of granular material that uniformly covers the area of the adhesive layer can be carefully and successively applied can be used, but a method wherein a large amount of granular material is scattered onto the sheet, and excess granular material (portion not bonded by the adhesive) is subsequently removed, is easy to use.

[0016] As for the removal of an excess granular material, a method wherein excess material is removed by vacuum is simple to use. But in this case, a vacuum is required. Also, a method wherein the excess portion is scraped off with a smooth and flat tool, or a method wherein the sheet is tilted to shake off the excess materials can be mentioned as well. The above-mentioned methods are convenient since special equipment is not required.

[0017] The shape of the sheet used in the present invention is not especially limited, and a wedge form or long sheet, as well as special shapes can be used. The material can be easily cut using a cutter, thus, it can be applied to any shape of area at the construction site. When a long sheet is used, it is convenient for it to be stored in a roll with a release sheet.

[0018] A synthetic resin (top coat) can be coated onto the surface of the granular material. When the above-mentioned treatment is provided, abrasion of the granular

material can be prevented and the ends of the optical fiber cable can be protected. It is desirable to use synthetic resins with good elasticity for this purpose. When a synthetic resin with good elasticity is used, the elasticity of the sheet with the granular material on it can be retained. For examples of the above-mentioned resins, acrylic resins such as MMA, urethane resins, and epoxy resins can be mentioned. In general, the above-mentioned synthetic resins are transparent, but pigments can be added to provide color. When a design is created using colors in some areas, different types of aesthetic effects can be achieved.

[0019] The amount of synthetic resin coated is preferably sufficient to cover at least 2/3 of the granular material. However, it is not especially limited, and a greater amount that covers nearly all of the granular material can be used, or a lesser amount can be used as long as abrasion of the granular material does not occur. Furthermore, it is possible to coat two different synthetic resins, one as the inner layer and one as the surface layer. In other words, a resin with a relatively high hardness can be coated as the inner layer to provide adequate containment of the granular material, and an elastic resin can be coated as the outer layer. Also, an adequate amount of a soft, flexible resin can be used as an inside filler and a hard resin can be coated on the surface.

[0020] Furthermore, coating of the synthetic resin can be done at the plant or at the construction site. In other words, the sheet without a synthetic resin is applied at the construction site, and a synthetic resin is coated or sprayed onto the above-mentioned sheet. The advantage of the above-mentioned method is that good adhesion and waterproofing at the joints can be easily achieved since the surface coating is done after installation of the

sheet. Also, the sheet itself can be stored as a roll when the synthetic resin is not coated. Thus, installation can be done in the form of a long sheet, and installation is easy.

[0021] In recent years, parts of roads are colored with different colors and dedicated to biking or jogging. In this case, when a long sheet of the present invention is installed for the jogging area, it becomes a shock absorbing zone, and color discrimination makes more sense. The zone can be clearly seen at night as well because of light emitted from the optical fibers.

[0022] In the following, the surface treatment method for buildings of the present invention is explained in further detail. In the method of the present invention, optical fibers are arranged under an adhesive sheet at the time of application of said sheet, the ends of the fibers are exposed and the fibers are secured when pressure is applied to the sheet. The rest of the procedure is the same as for the above-mentioned sheet. In other words, a granular material can be applied to the surface, or a sheet that already has a granular material on the surface can be used.

[0023] In the following, the sheet application method in which granular materials with different colors are used in some areas (to form a pattern) is explained further. A pattern having a release sheet on the back surface (not necessary when peeling is easy) is applied to an adhesive sheet, a granular material is scattered onto the above-mentioned laminate, and the pattern is removed after removing the excess [granular material], a granular material with a different color is scattered onto the area previously covered with the above-mentioned pattern to bring out the design. When several different patterns are used, and the above-mentioned process is carried out repeatedly, a multi-color design is

produced. The material used for the pattern is not especially limited, and paper, plastic sheeting, etc. can be used. Also, the pattern can be produced using methods such as punching according to the desired design.

[0024] In order to light the optical fiber cable, naturally, a light source is required. In this case, a standard type can be used. For example, a simple electric bulb can be used. Furthermore, a rotating sector, etc. can be used and the color can be changed with time. And the equipment required is well known in the decorative design field and is commercially available.

[0025] Furthermore, light sources can be installed anywhere, and the location is not directly related to the present invention. For example, the light source can be installed underground near the area where the sheet is installed, or inside the building. Also, the light source can be automatically or manually turned on and off at specified intervals, or automatically turned on and off based on daylight or darkness.

[0026]

[Application examples] Fig. 1 is a perspective view that shows an example of the adhesive sheet for the surface of a building 1. Many optical fibers 3 are secured to the back of butyl rubber sheet 2, and one end 4 of each optical fiber is exposed to the surface. Also, release sheet 5 is applied to the back surface so as to sandwich the above-mentioned fibers 3. Furthermore, an orange colored granular material is applied to the entire front surface of the above-mentioned sheet 1.

[0027] Fig. 2 is a cross section that shows the above-mentioned sheet 1 installed on sidewalk 7. Light source 9 is installed in pit 8, and light enters the end of the optical fiber. A cover is placed over pit 8 so that it does not interfere with walking.

[0028] Fig. 3 is the top view showing the sidewalk with the above-mentioned sheet installed. Bright light is scattered along the sheet and it is bright and beautiful at night, and it gives walkers the impression that they are walking across the night sky.

[0029]

[Effect of the invention] The adhesive sheet for surface of buildings and the surface treatment of buildings of the present invention has the major advantages described below.

(1) Surface treatment of buildings is made simple.

(2) Light can be emitted by simple means since optical fibers are used.

(3) Buried light bulbs or other equipment are not required; thus, burnout and breakage do not present problems.

(4) Installation is easy, and compared with conventional sheet installation methods, the cost is not necessarily high.

(5) Good aesthetic effects can be achieved even at night, and the position of buildings can be seen easily.

(6) When used in combination with a surface treatment, the effect of the installation can be achieved all day long, as well as at night.

[Brief descripti n of the figures]

[Fig. 1] The figure is a perspective view that shows an example of the adhesive sheet for the surface of buildings 1.

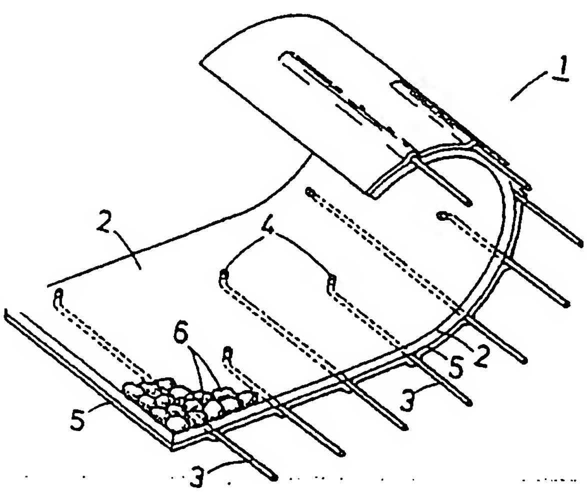
[Fig. 2] The figure is a cross section that shows application of the adhesive sheet of Fig. 1.

[Fig. 3] The figure is the top view of Fig. 2.

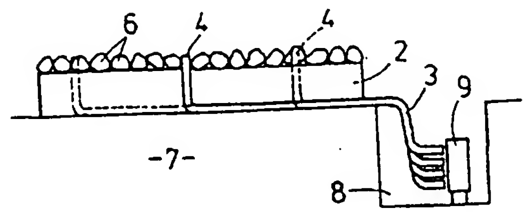
[Explanation of codes]

1: Adhesive sheet of the present invention
2: Butyl rubber sheet
3: Optical fibers
4: One end of fibers
5: Release sheet
6: Granular material
7: Sidewalk
8: Pit
9: Light source
10: Scattered lights

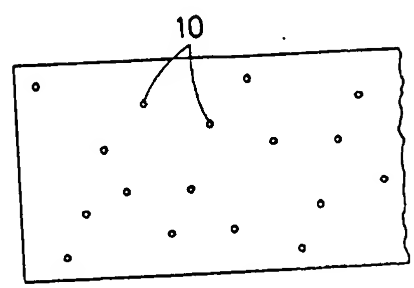
[Fig. 1]



[Fig. 2]



[Fig. 3]



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Flexible Optical Backplane Interconnections

M.A. Shahid and W.R. Holland
Bell Laboratories,
Engineering Research Center,
Lucent Technologies Inc.
P.O. Box 900, Princeton, NJ 08542, USA

Abstract

The increasing demand for bandwidth and interconnection density to provide wide bandwidth services at reasonably low cost are rapidly exhausting capabilities of interconnection techniques currently employed in conventional wide bandwidth telecommunication switching equipment. In particular; a bottleneck occurs at the intra-system (that is, board-, shelf- and cabinet-level) backplane interconnections. In order to address this problem, a variety of optical interconnection schemes have been proposed. At Lucent Technologies Bell Laboratories, we have taken a systems approach in developing a Z-axis assembly process for producing flexible optical backplane interconnection circuits. This paper describes details of fabrication process and performance of new flexible optical circuits.

Introduction

In order to take full advantage of technological advances of the high speed IC's in new broadband switching, communication and computing systems, concomitant advances in traditional interconnection technologies, in particular at the system's backplane-level, are necessary (1,2,3). The current electrical backplanes suffer from a major performance limitation; due to the EMI problem, an electrical backplane operating at bit rates of >200 Mb/s becomes inefficient and hence expensive. Optical interconnections are attractive due to their freedom from the EMI problem and extremely large bandwidth. Therefore, the system designers have started to introduce and implement optical interconnection products into next generation wideband systems. This has created a real need for efficient intra-system (that is board-, rack- or shelf- and cabinet-level) optical backplanes.

Consider a shelf-wide optical backplane of a typical system. It consists of a distributed network of optical transmission lines with terminations provided at appropriate points such that all circuit cards in the shelf can be plugged into the backplane in order to efficiently transport and distribute optical signals. This requires a high concentration of optical transmission lines and optical add/drops within a relatively small area. There are two main challenges: providing an organized network of low loss, low noise/cross-talk optical transmission lines, and terminating those with appropriate connectors. Clearly an optical backplane is highly connector intensive. In certain applications, e.g., a synchronous system, each optical transmission line in the backplane may require equalization of optical path for minimizing skew.

The most common and perhaps the simplest approach for implementing an optical backplane uses discrete optical fiber jumper cables to interconnect the optical i/o's on circuit boards in the shelf or neighboring shelves of a system cabinet. This approach has the advantage of providing point-to-point signal paths with flexible routing and distribution between the end-points. Also high performance connectorized (with FC, ST, SC, etc. connectors) jumper cables made from a variety of optical fibers (single-mode, multi-mode, polarization maintaining, etc., and different coating and jacket materials) are commercially available. Since propagation loss at such short distances is insignificantly small in most commercial optical fibers, loss margin requirements can be easily met in most situations.

Although this simple approach has merits, it also suffers from serious limitations. When the interconnection count is large (10's to 100's of optical connections), which is the case in a typical optical backplane of a reasonable size, in addition to their high aggregate cost, management of a large number of fiber cables also becomes a serious problem. The restrictions

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on minimum bend radius of an optical fiber further complicate the problem. Also when the connector count on each circuit card becomes large, which would be the case in most multi-channel parallel interconnections, the space for connectors on the board, face-plate and/or backplane can also become a serious limitation. Although miniature single-fiber connectors have been developed to solve the space related problems (4), these connector are too expensive for most high connector count applications.

An alternative to using single fiber cables is the use of multi-fiber ribbon cables (MRCs). The repeat distance of fibers in the array constituting a MRC is usually 0.25 mm (which is equivalent to a linear density of 40 fibers per cm). Multi-fiber connectors are also commercially available for termination of MRCs (5-8). The MRCs terminated with multi-fiber connectors are attractive only for providing high density optical interconnections where all point-to-point connections in the cable start and finish on the same two boards. In a real system, distribution, configuration and grooming of optical signals is often necessary. This means that the optical fibers of a given MRC must be 'fanned-out', that is split into individual fibers, and re-ribbonized after mixing with fibers from other 'fanned-out' MRCs to efficiently transport, properly configure, and/or reconfigure optical signals between different processing units of the system. This requires fabrication of complex multi-fiber harnesses of custom design, which is expensive.

Several different techniques have been proposed for the termination of MRCs (5-10). The two types of commercial multi-fiber connectors both require 'free-end' of a MRC for connectorization. The glass fibers are stripped of their protective coating and strength members, and then bare glass fibers are inserted into the holes of a multi-fiber connector ferrule/plug and bonded using an epoxy adhesive. Usually large length margin (of several inches) at the to-be-connectorized end of a MRC is required for re-attempts. The rate of completing a connector at the first attempt is generally low because of the fragile nature of stripped fiber which can easily break during insertion into the connector ferrule. If any fiber of an array breaks inside the ferrule, that ferrule may not be used again. This means that the MRC will be cut back for making another attempt using a new ferrule. This also means that the length equalization of optical transmission lines of the optical backplane harness for a synchronized system is more difficult to achieve. Moreover, the unequal slack at the ports of such a backplane could also pose cable management problems.

Recently, several alternatives to using discrete fiber cables or MRCs have been proposed. The optical backplane of the multi-dimensional optical network is one such example (11-13). Here an array of single-mode D-fibers (with cores ~1 μm below the planar facets) was embedded into a rigid board. The planar facets of all D-fibers constituting a parallel optical bus architecture were set in the surface plane of the board. Another identical D-fiber structure was fabricated at the far-edge of each circuit board. The backplane board was installed at the back of the shelf in such a way that its surface containing the planar facets of the D-fibers was facing the planar facets of the D-fibers at the far-edge of the circuit boards. By bringing together into physical contact the planar facets of D-fibers in the backplane and those at the edge of the circuit board, optical interconnection was established through evanescent field coupling. The coupling efficiency was adjusted by controlling the coupled length (that is the length of the overlapping core regions of mating fibers, which in turn depends on the angle between the fiber axes). This elegant and innovative approach has serious limitations for real system applications. Only D-fibers can be used to produce this highly specialized optical backplane. Besides being expensive, the backplane is optically 'leaky' and structurally fragile (the fiber cores in connectors at the edge of circuit boards and the backplane - which must come in physical contact to make the optical connection - are only ~1 μm below the planar facet of the D-fiber). Thus long term reliability of such an optical backplane is a serious problem.

In another example, polyimide coated fibers were routed and bonded to the surface of a rigid board to produce electro-optic backplane structures (14,15). The board surface was pre-coated with a stage-B (i.e., partly cured) epoxy. During fiber routing, the machine head locally melted the epoxy (by delivering ultrasonic energy) and bonded the fiber to the board. The point where an optical connection was desired, a local 'bump' or 'ramp' was created in the path of the fiber. Later, the bumped region was polished away to produce a localized 'D-fiber' configuration. Another planar facet similar to the one on the backplane board was also prepared on the fiber attached to the far edge of the circuit board. Thus despite its structural dissimilarity from that of the D-fiber interconnection scheme described above, the connector schemes in the two cases are somewhat similar. Also this technique uses polyimide coated fiber which is several times more expensive than the more common acrylate coated fiber. Moreover, the required specialized connectorization

techniques and connector assembly processes make this type of optical backplanes too expensive. Long term reliability of ultrasonically bonded fibers is also an issue.

Another techniques relates to the so called 'smart skins' optical backplanes (16). Here after 'weaving' fibers into a desired pattern and holding them in place, the fiber fabric is set into a molding compound to produce a rigid structure. It is not clear how easily the required optical connections are made to the embedded fiber and maintained for prolonged use of a system.

At Bell Laboratories, we have taken a systems approach to overcome this important optical interconnection bottleneck. Our goal was to identify and develop enabling technologies for producing complex intra-system optical backplanes at reasonably low cost. This has resulted in the development of a Z-axis assembly process whereby truly flexible, fully connectorized, large optical backplane circuits are produced by applying processes, materials and parts sequentially in the vertical (Z-) direction (17-19). The process consists of, designing the required circuit layout including fiber paths, length equalization (if required), boundary shapes, etc., using a commercial CAD tool, routing of single length of a fiber of desired type according to the CAD design using a dedicated computer controlled workstation which can control the fiber length to less than a mm over a work area of 30x30 inch, laminating the fiber circuit, cutting circuit boundaries using computer controlled machine, mechanized stripping coating from localized, uncut fiber lengths precisely and reproducibly, applying molded plastic split multi-fiber connectors using another computer controlled workstation, and terminating and polishing connector ends. The required split connectors were injection molded from heavily filled commercial molding compounds. In this paper, details of the Z-axis assembly process for producing connectorized optical Interconnection circuits (COICs) are described.

Flexible Optical Circuit Technology

As pointed out above, optical circuits are fabricated by a sequential application of processes, materials and parts in the Z-direction (17). Thus each element of the fabrication process can be a stand-alone operation, and the same carrier board is brought to each workstation in order to complete its own particular operation. A schematic of the process flow is shown in Fig. 1. In the following, details of the Z-axis assembly process are described.

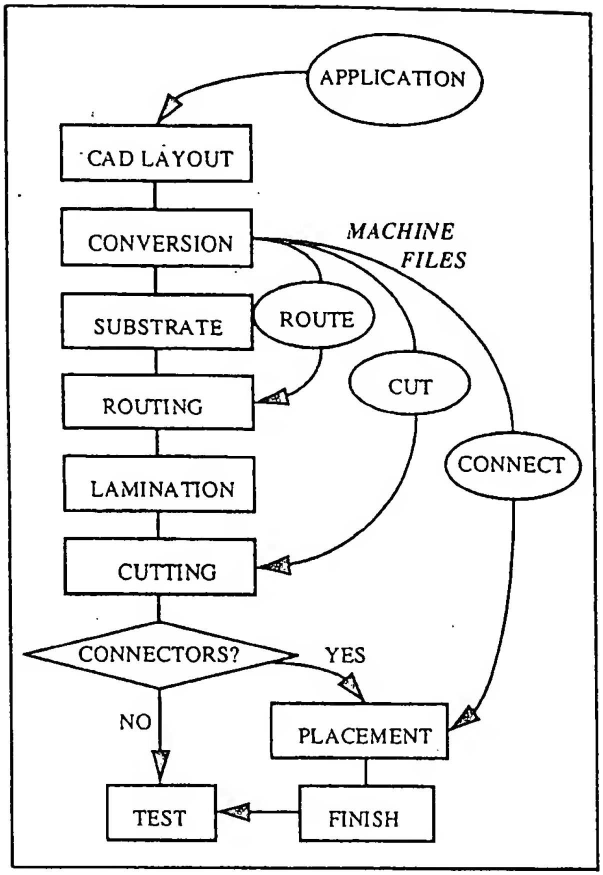

Fig. 1 Process flow for producing optical backplane circuits.

Circuit Layout Using a CAD Tool:

Once an application has been identified and its interconnection requirements analyzed, a CAD tool is used to design a scaled drawing of the required circuit. This includes the line drawing depicting the interconnection paths, number and relative positions of ports, number of i/o's in a port, the circuit boundary, etc. (Fig. 2). One essential element of the CAD drawing is that a single continuous line of the whole circuit is generated. This line cross-connects the required ports of the circuit. If needed, precise length equalization of each interconnection path can be incorporated into the design. A 1" or greater bend radius is typically included wherever the fiber must turn for a change of direction. Also created is the general shape of the circuit boundary. Thus, number and position of i/o ports,

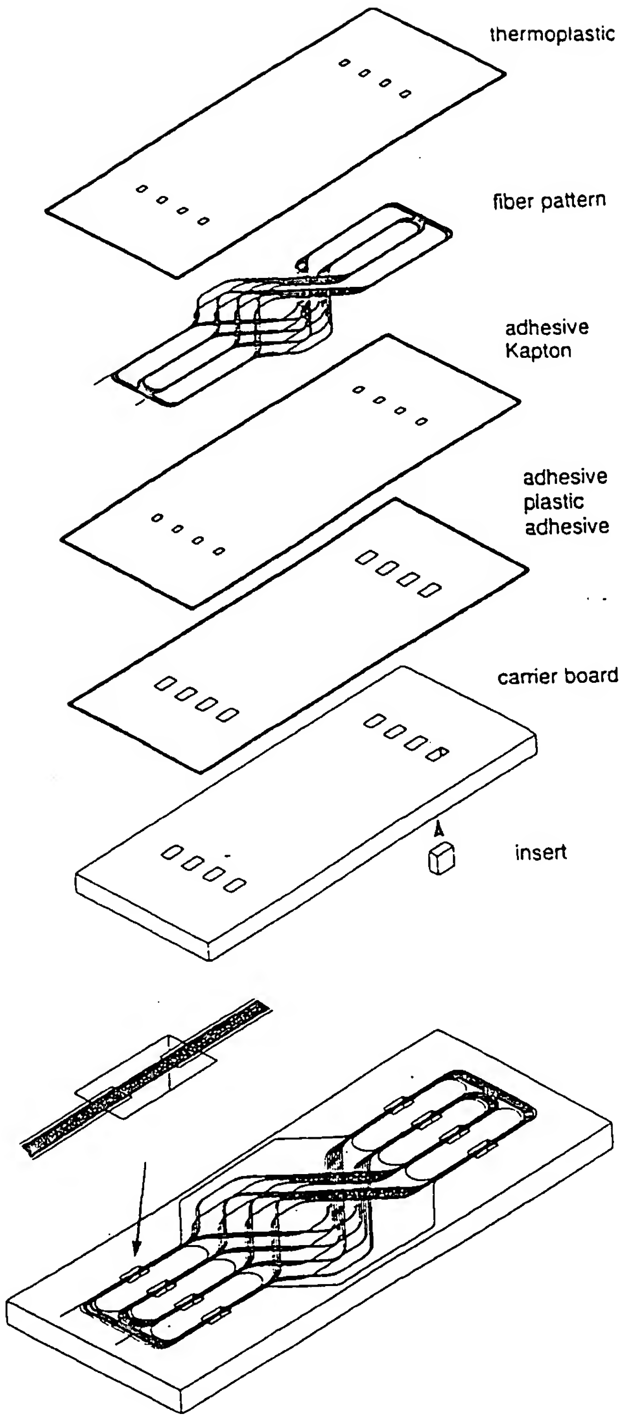

Fig. 2. Schematic drawings showing the process flow for the Z-axis assembly of flexible optical circuits.

position of fiber cross-overs, and shape of the circuit boundary, are all included in this scaled line drawing. Next, data files for the routing paths, connector port locations and circuit boundary for later use are extracted from the original CAD file.

Circuit Fabrication:

A rigid carrier board of size large enough to accommodate the fiber circuit is prepared. This board has apertures with a temporary blocking mechanism to keep work surface of the board planar. With apertures unblocked, top surface of the board is coated with light adhesive. After blocking the apertures, a sheet of plastic material is attached to the board. This sheet, which has a pressure sensitive adhesive applied to its top surface, is the substrate on which the fiber circuit will be produced. This sheet also has apertures at the connectorization locations, although somewhat smaller than those of the carrier board. The board is mounted on the fiber routing workstation. The drive mechanism of the fiber routing head is commanded by the data file extracted from the CAD file for the routing routine. As in the CAD design, the routing head presses the fiber into the adhesive as it cross-connects the fiber between different ports of the circuit. In a way the final circuit is a complex open-ended loop of a single fiber length which has many right-handed and left-handed turns along its path. Fig. 3 shows a finished circuit displaying optical continuity where HeNe laser light is injected into one end and after propagating through the entire circuit, it emerges at the other end. At every point the fiber is required to make a change of direction, a bend radius of at least 1" is maintained. After completing the circuit, the board is removed from the workstation, and another sheet of plastic material is laminated on the fiber circuit. This protective sheet also has apertures at the connectorization locations. A commercial laminating press is used to bond the top sheet on to the fiber fabric using a suitable level of heat and pressure.

Once again the board with the laminated circuit on it is mounted on the routing workstation which now is equipped with a cutting head replacing the routing head. Using the data file for the circuit boundary, the circuit is cut into its final shape, including its multi-fiber i/o ports (alternatively, cutting can be performed later after all connectors have been attached to the circuit). This completes the optical interconnection circuit. If it does not require addition of connectors, which may be the case when it is to be spliced into the system, it can be tested. After cutting the excess fiber ports, the circuit is peeled off the board and is ready for use in the intended

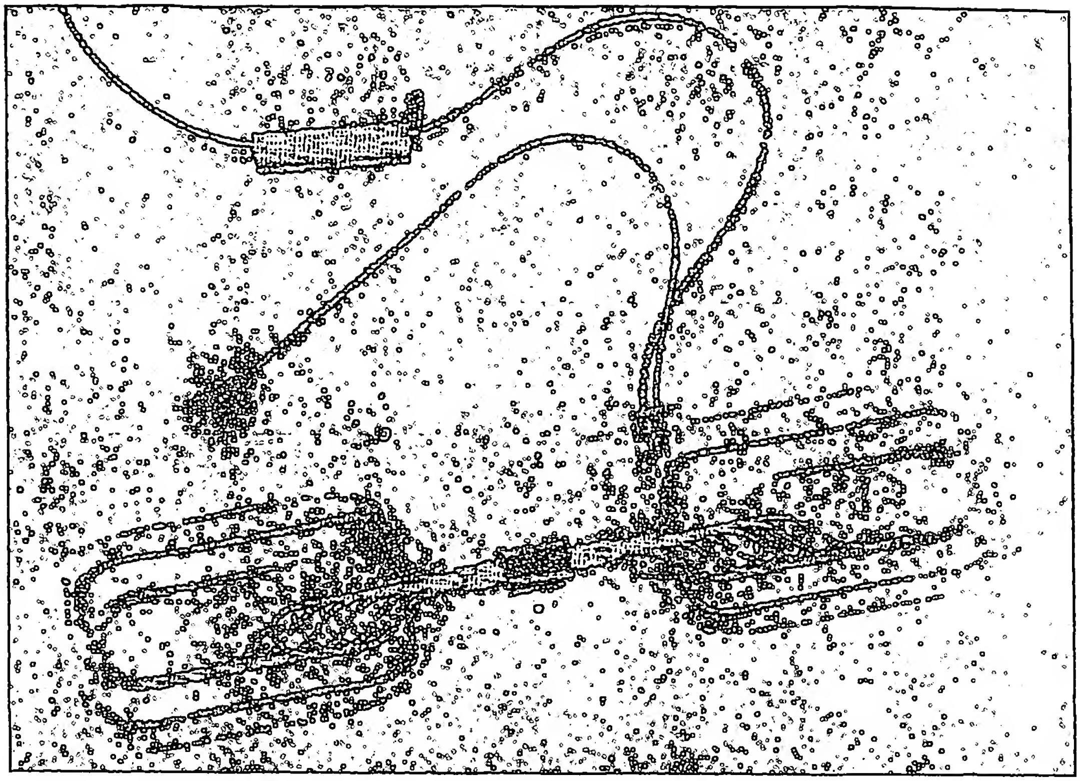

Fig. 3 A photograph showing an optical continuity test after completing the circuit.

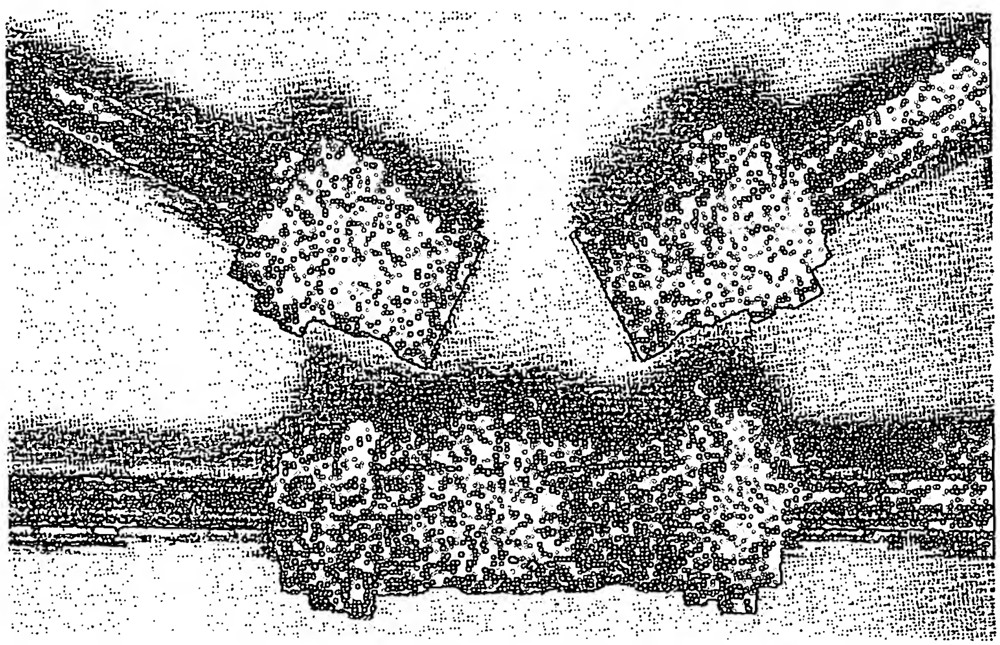

Fig. 4 A multifiber ribbon cable terminated with a "double-length" connector. After cutting through the double-length connector, one gets two connectorized ends of the multifiber cable.

application. This may require further processing, such as stripping and cleaving fiber ends at each port for the (mechanical or fusion) splicing process.

Split Muti-fiber Optical Connectors

The Z-axis assembly of COICs requires split connectors. The 10-, 18- and 32-fiber split connectors, which were compatible with the commercial multi-fiber connectors, were designed and injection molded from commercial heavily filled molding compounds such as polyphenylene sulphide (20, 21). Precision section of each connector was precisely reproduced from a V-groove master Si chip of corresponding design by a Ni-electro-forming process. This produced an inverse replica of features of the Si master chip. The electro-formed Ni-replica was machined and used as an insert in the injection mold. The dimensions of the V-grooves in the master Si chips were over-sized to compensate for the mold shrinkage (for details see ref. 20) Both single- and double-length split muti-fiber connectors were produced. The double-length connector, which also had a built-in latching mechanism, was designed for applying to middle, un-cut sections of MRCs and common ports of simultaneously routed pair of optical circuits (such as those shown in Fig. 3). Cutting through the middle of double-length connectors provides two connectorized multi-fiber cable/circuit ports. Fig. 4 shows a picture of a connectorized MRC before and after cutting through the double length connector/fiber assembly. The doubled throughput of the connectorization process could prove highly effective in producing low cost COICs.

Localized Stripping

When the COICs are required, the fiber circuit produced above is not peeled off the board but stays attached to it for the connectorization process. If the fiber used for producing the circuit has acrylate coating, it must be stripped at the connector locations before attaching connectors. For stripping and connectorization processes, the apertures in the carrier board are unblocked. This leaves the fiber ports suspended across the apertures and accessible from both sides. The board is mounted on the workstation which is a 4-axis machine, consisting of an xy-stage and two z-stages, one mounted above and other below the xy-stage. Both z-stages, which only move up and down, i.e., along the z-direction, are pre-aligned with each other and have stripping and connectorization mechanisms attached to their ends facing the xy-stage. All four axes of the workstation are computer controlled and can be programmed to step-and-repeat the stripping and connectorization processes on all ports of the circuit.

With the Z-stages withdrawn, the desired multi-fiber port of the optical circuit is brought in position by the xy-stage. The lower Z-stage is raised such that the to-be-processed section of the fiber port sits on, and bridges across the central part of lower blades of the stripping mechanism. The coating softening agent is applied to the fiber section and the upper Z-stage is lowered in position. Next the stripping mechanism is activated to remove the softened coating. The Z-stages are withdrawn and the stripped fiber port is cleaned. The process is repeated until all fiber ports are stripped. The operation of the stripping mechanism was optimized to ensure that it does not damage, e.g., scratch, the glass fibers. The measured strength of stripped fibers confirms that the quality of fibers does not degrade (20). Fig. 5 shows a typical stripped multi-fiber port. Ability to strip localized, un-cut, sections of MRCs and circuit ports is critical for achieving doubled throughput of the connectorization process using double length connectors. Conventional stripping (and connector assembly) processes require a 'free-end' of a fiber cable.

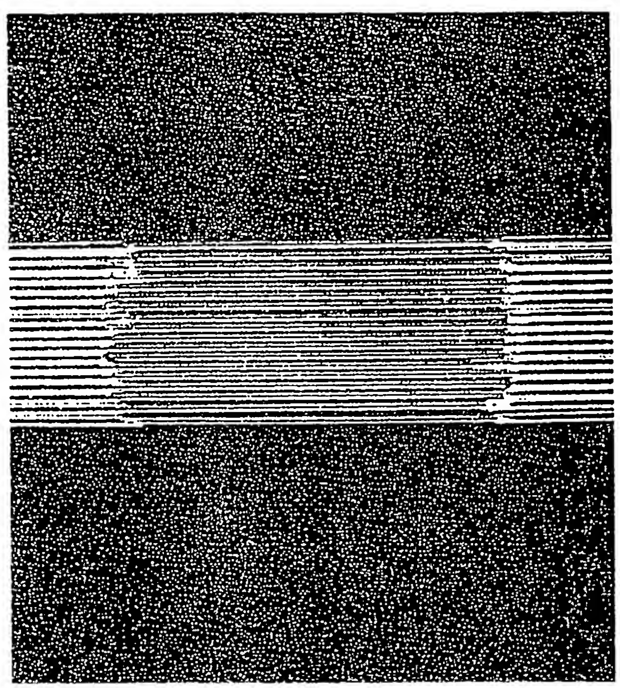

Fig. 5. A photograph showing stripped region of a multi-fiber port of a flexible optical circuit.

Connectorization Process

A pair of magazines to hold split connectors as aligned pairs with fiber-grooves facing each other, are also attached to the xy-stage. The xy-stage is programmed to position the magazines between the two Z-stages for picking the split connectors. The Z-stages are lowered toward the magazines. The vacuum lines attached to each connector pick-up head are activated. Thus the pre-aligned connector halves are held in position under vacuum induced suction. The Z-stages are withdrawn, and the to-be-connectorized port of the fiber circuit is brought in position by the xy-stage. Next the Z-stages are lowered toward the multi-fiber port where the split connectors sandwich the fibers and are bonded with an epoxy adhesive. The connectorization cycle is repeated until all ports of a circuit have been completed. Fig. 6 shows multi-fiber ports of a circuit at different stages of assembly.

At this stage an optical test can be performed to ensure structural integrity of the completed circuit. If the circuit boundary needs cutting, the carrier board with the connectorized circuit on it is mounted back on the routing machine which is now equipped with the cutting head. After cutting the boundary, the circuit is peeled off the board, excess fibers at the i/o ports are cut and the connector ends are polished. Now the circuit is ready for its intended application.

Optical Performance

A variety of COICs were produced by the Z-axis assemby process described above (for example, see Fig. 3 in this paper, and Fig. 8 in ref. 17, and ref. 22). The circuits were subjected to a variety of environmental conditions and have shown good reliable performance (20). This work is still continuing. The optical performance of connectors is also very good. For example, 18-fiber ribbon cables produced by the routing process using polyimide coated multi-mode fiber (core diameter=62.5µm), were connectorized using split connectors. The 10-µm thick polyimide coating was not removed during these experiments. An average loss of 0.5 dB was measured with highest and lowest values of 1.0 and 0.26 dB, respectively. Repeatability of each connection of the array was ≤ 0.1 dB.

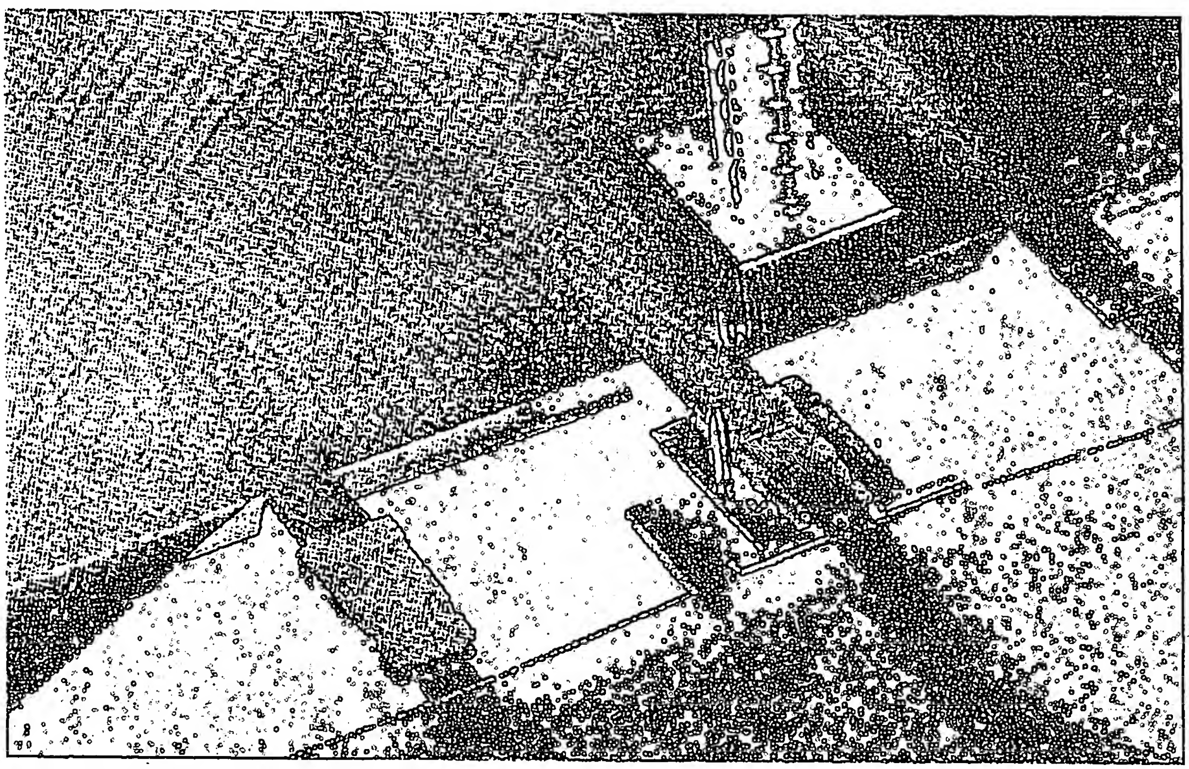

Fig. 6 A photograph showing multi-fiber ports of a flexible optical circuit at different stages of connector assembly.

Summary

We have described a new technology for producing complex optical interconnection circuits for backplanes of wideband communication equipment. The circuits are built in the Z-direction by sequentially applying processes, materials and parts. The Z-axis assembly process can be mechanized. The circuit design uses a commercial CAD tool which provides data files for the workstations to complete different stages of the circuit assembly, such as, fiber routing, cutting, fiber stripping, connectorization, etc. Moreover, accurate length control can be incorporated into the circuit design. The idea of completing an interconnection circuit from a single fiber length is useful since it allows monitoring of the optical continuity of the routed fiber at different stages of fabrication. Split connectors are necessary for mechanized mass termination of fiber circuits. These connectors were injection molded from commercial molding compounds. Every element of the Z-axis assembly process was developed to keep the overall cost of a completed circuit as low as possible. With COICs now available, the system designers have truly flexible and efficient tools for managing high count optical i/o's of broadband systems.

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